7-1971

Haptic perception of the Mueller-Lyer illusion by the blind

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HAPTIC PERCEPTION OF THE MUELLER-LYER ILLUSION BY THE BLIND

A Thesis

Presented to the

Department of Psychology

and the

Faculty of the Graduate College

University of Nebraska at Omaha

In Partial Fullfilment

of the Requirements for the Degree

Master of Arts

by

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July 15th, 1971

Accepted for the faculty of The Graduate College of the University of Nebraska at Omaha, in partial fulfillment of the requirements for the degree Master of Arts.

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ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Mrs. Berit Yank, of the Nebraska Services for the Visually Impaired, whose able assistance made this study possible. A debt of gratitude is also owed to Dr. Kenneth A. Deffenbacher, major adviser on the thesis committee, Dr. Shelton Hendricks, Dr. Edward LaCrosse, and Dr. C. Raymond Millimet for their excellent advice and invaluable suggestions.

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ABSTRACT

This study measured the extent to which the following four groups of Ss experienced the Mueller-Lyer illusion: a group of ten congenital blind, ten Ss blinded in adulthood, ten sighted blindfolded Ss presented the illusion haptically, and ten sighted Ss presented the illusion visually. All of the groups experienced the illusion to a significant extent. The extent of illusion in the sighted haptic group was significantly less than that in each of the other groups, $p < .025$ in each case. None of the other pairs of means were significantly different. Thus the results show that the blind do experience the Mueller-Lyer illusion similarly to the sighted, but the extent of illusion is much less for the sighted blindfolded. A positional memory hypothesis was presented to account for these results. It proposes that the blind have learned to remember the haptic location of objects in their environment but that the sighted have not developed this skill to the same degree.

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An old problem in space perception has been the question of whether visual illusions are "central" or "peripheral" phenomena. An outstanding example of a central theory of visual illusions is that of Révész (1950). He proposed that space illusions are not secondary and isolated phenomena peculiar to one sense modality or another but are, rather, consequences of the operations of a common basic function which underlies all space perception. Certain optical illusions are not merely peripheral effects in the eye itself, but are distortions in higher integrative processes regardless of whether they are perceived by touch or vision. Other well known central theories include Thiery's perspective theory, Koffka's prägnanz, or good figure theory, and Lipp's empathy theory (Carter and Pollack, 1968). Examples of peripheral theories are Wundt's eye-movement theory and Einthoven's retinal image theory.

One approach to the central-peripheral controversy is the application of the cross-modal method, which is relevant in testing peripheral and central theories in that, when the illusion figures themselves are apprehended in more than one sense modality, but the illusion effect is perceived in only one sensory mode, the inference can be made that it is likely to be a peripheral effect. Conversely, if the same stimulus effect is perceived in more than one modality, the inference can be drawn that it is probably a central effect.

Examples of the cross-modal method applied to central and peripheral theories are studies which compare the responses of blind subjects presented visual illusions haptically, with the responses of sighted persons presented the same illusion visually. The basic question these studies have been addressed to is whether an illusion is purely a visual one or whether it is perceived by touch also. If the illusion is perceived similarly by touch in the blind as it is by vision in the sighted, it is possible to infer that a central process is involved.

Research in visual illusions with blind subjects is not frequently encountered in the literature; apparently, only four studies have been done. The first of these (Révész, 1934) using standard optical illusions which were constructed for haptic perception, compared results from three types of presentation: (1) sighted Ss perceiving the illusion visually (2) blind haptic active (free movement of the hands) (3) blind haptic passive (placing the hands over the figures without movement). He found that blind Ss were susceptible to the illusion in both methods. However, he did not include a sighted blindfolded group perceiving the illusion haptically.

Bean (1937) reported an experiment using optical illusions of active touch in twenty-eight children, adolescents, and adults, all totally blind, and all but three blind from birth. The illusion scores of this group were compared with scores of twenty-eight children, adolescents, and adults with normal sight. He used six types of visual illusion figures which were constructed so that the lines were in relief and could be apprehended by touch. His results showed that the blind experience in high but varied degrees, the illusions in active touch that sighted persons do visually. He also found that blindfolded sighted Ss do not have the illusions in active touch.

Hatwell (1960) using geometrical tactual illusions, tested the hypothesis that "field effects and the internal structure of geometrical figures are less pregnant and less coercive in tactile perception than in visual perception." Raised figures were presented to completely blind children and the results compared with those of sighted children. She found that "there appears to be a significant attenuation of the illusion effect in blind children for the vertical-horizontal and Mueller-Lyer illusions and a total absence of illusion for the Delboef and Halteres figures."

Tsai (1967), using a cardboard apparatus embossed with Braille lines, found that nine blind Ss (three born blind, three blinded in childhood, and three blinded as adults) all exhibited the haptic illusion (Mueller-Lyer) comparable to the same illusion in four sighted Ss, perceiving the illusion figures haptically. He also found that the blind Ss experienced the illusion similarly to a group of four sighted Ss experiencing the illusion visually. Subjects blinded at birth or in childhood showed a greater illusion effect with the preferred hand, than with the non-preferred hand.

A pilot study conducted by the author, preliminary to the present study, found that eleven blind Ss showed a pronounced susceptibility to the Mueller-Lyer illusion. The apparatus was made of wood and both figures were adjustable, which yielded quantitative measures of the extent of the illusion. The error score of the blind Ss was consistently in the direction of the illusion and was compared statistically against a hypothetical mean score of zero. The assumption in this procedure is that if there is no illusion effect, then over a large number trials the mean error score would be zero. This t test for a true mean was significant, $p < .001$, which showed that the blind did in fact experience the illusion.

These studies leave considerable room for doubt as to whether or not the blind subjects were indeed comparing only the lengths of the mid-portion of the Mueller-Lyer illusion and not the total length of the figures. If the Ss were in reality comparing the total length of the figures, then the results would not reflect the actual extent of the illusion. The error score would then merely show the additional length of the end patterns of the figure with the outgoing vanes, a measurement erroneously taken to be the actual extent of the illusion. Experience obtained in the pilot study by the author revealed the difficulty in making clear to the blind Ss just what the experimental task consisted of, and in addition, aroused the suspicion that the above interpretation may have been in actuality, what many of the Ss in previous studies thought the experimental task was. Morover, there are a considerable proportion of legally blind persons, probably over fifty per cent, who have some residual vision. Hence, the possibility exists that many of the "blind" Ss in the older studies may actually have been able to see the illusion figures. In the Révész study, there was no sighted haptic control group to provide a comparison for the other groups. A large proportion of Bean's Ss were children and Hatwell's Ss were all children. This may have been a factor in the large amount of variability reported in the Bean study. It would appear that making the experimental task clear to children would be even more difficult than with adults.

The present study resembles all four of these previous studies in that it is concerned with the question of whether or not the blind are subject to the effect of the Mueller-Lyer illusion by touch. The instructions were written so that any possibility that Ss were comparin the total length of the figures was definitely precluded. In the present study, Ss were interviewed prior to the experiment to ascertain if they had any residual vision, and if so, they were required to wear a blindfold. A problem in the previous studies was the large amount of variability encountered in the haptic groups. Two steps were taken in this study to alleviate the difficulty: only adult Ss were used, and a repeated measures analysis of variance design was used to minimize experimental error. The additional rigidity and stability of the metal illusion figures in contrast to the cardboard figures in previous studies may also have reduced response variability. An attempt was also made to influence the Ss set to respond to apparent size-equality, rather than objective size-equality (Over, 1968). If the Ss regard the task as a test of ability, one should expect that they would disregard the end patterns of the figures as much as possible, or use other task irrelevant cues to obtain a high score (objective size-equality). But, if they are instructed or suspect that the figures are an illusion, then it might be expected that they would attempt to correct for it. Hence, they were instructed that the purpose of the task was to determine the effect of the end patterns on judging the lengths of the middle lines.

The specific purposes of this study were (1) to conduct a better controlled study than performed heretofore (2) to determine if the blind are subject to the effects of the Mueller-Lyer illusion in a systematic way, and (3) to determine if there are significant differences among a congenital blind group, a group blinded as adults, a group of sighted Ss perceiving the illusion visually and a group of blindfolded Ss perceiving the illusion haptically.

Method

Subjects. Two groups of blind Ss were used: a group of ten who had been blind since birth, and a group of ten who were blinded later in life. Ss in the latter group ranged from one S, age 51, who had been blind for a period of 36 years, to another, age 44 who had been blind for only six months (see appendix, Table 1). The mean age of this group was 42.7, and the mean length of blindness was 116.6 months. There were six male and four female Ss in the group, all of which were totally blind with the exception of one person who had an estimated five percent vision. This S was the only one in the group who was required to wear the blindfold.

Ages in the congenital blind group ranged from 18 to 55 with a mean of 36.2. One person in this group also had some residual vision and wore the blindfold during the test. One other person had "light-dark" vision in one eye. There were five male and five female Ss in the congenital group. Of the total blind group, 11 were employed or were housewives.

Fifteen of the 20 blind Ss were obtained with the assistance of the Nebraska State Services for the Visually Impaired. The remaining 5 were obtained by the author at the Roberts Manor residence for the visually impaired. They were all volunteers, and were paid three dollars for participating, with the exception of eight of them, who refused to accept payment even though it was offered.

The twenty sighted Ss were obtained from the introductory psychology class at the University of Nebraska at Omaha, and consisted of 3 males and 7 females in the blindfolded haptic group and 5 males and 5 females in the visual group. These Ss were all volunteers for this particular experiment. Their mean age was 22.2 years.

Apparatus. A pair of Mueller-Lyer figures were constructed of metal tubing and wood, painted white, and mounted on a plywood board with metal brackets. The angles of the vanes were 45 degrees to the center shaft. The board itself was covered with black felt. The figures were adjustable in length from a minimum of 23 cm. to a maximum of approximately 38 cm., with the adjustable ends sliding inside the stationary portion of tubing. The adjustable ends were both on the same side of the figures. The arrows were mounted parallel and were a distance of 18.5 cm. apart. The board was a 6 sided polygon with the top and bottom edges parallel and 44 cm. apart. The left and right edges were cut in an eccentric manner to discourage use of the edges as cues, and the board was 59 cm. wide at the widest part. For the haptic Ss, a small pin was inserted in the sliding portion, and rode in a horizontal slot in the fixed portion to stabilize and tighted the sliding part. The feet of two of the brackets were covered with black felt to preclude their use as cues for the visual Ss, and during the trials, the ends of the tubes were covered with a short piece of opaque white tape to hold it in position at the standard length of 28 cm., and to prevent Ss from using the edge of tube as a cue. A stand was attached to the back of the board to support it in a position 18 degrees from the vertical.

Procedure. The following instructions were read to the blind and the sighted blindfolded groups:

> This is not an intelligence test, and there is no hoax or tricks involved. Feel the whole apparatus over carefully to get an idea of what it is and how it is shaped.
>
> Will you please describe to me how the figures on the board are shaped. Can you feel how the end pattern slides back and forth? The other end slides also but I have it taped in place.
>
> What I would like for you to do is to equalize the lengths of the long middle parts of the two figures by sliding the end back and forth.
>
> Let me place your fingers on the parts I'm talking about. Make this distance here between your two hands equal to this distance here. It is the distance between the two points on this one, and the distance between the inside part of the two Vs on this one. Will you tell me now what you're supposed to do? You may use your hands in any way you like. I will tell you when to start.
>
> We will do ten trials with the moving part in each of the four positions, upper right, lower right, upper left, and lower left, for a total of forty trials. I will reset the starting

> position of the moving part before each trial.
> The purpose of the experiment is to see what effect the end patterns on the figures have on judging and matching the lengths of the middle parts. This part is very important. Do not attempt to line up the ends by merely setting one vertically under the other. Do not attempt to use any other cues from the board. Imagine the whole figure and make your judgements by actually comparing the middle parts. If you do it any other way you'll be cheating.

For all of the blind Ss, the trials were conducted on a kitchen or dining room table in their apartments and homes. The board was placed on the table before them a foot from the edge of the table. For both groups of sighted Ss, the trials were conducted in the university laboratory, and as in the blind group, the board was placed on a table at a distance one foot from the edge.

Four presentation positions of the illusion figures were used, depending on the location of the part of the figures which S was manipulating:

1. Short figure above--S manipulates lower figure.
2. Short figure above--S manipulates upper figure.
3. Long figure above--S manipulates lower figure.
4. Long figure above--S manipulates upper figure.

Ten trials were conducted in each position for a total of forty for each S. The order of the presentation position was randomized for each S, as was the starting position of the adjustable part of the figure for each trial: above or below the standard length of 28 cm., and at a random distance above or below.

The same instructions were used for the sighted blindfolded group as for the blind groups. These Ss were blindfolded with a pair of plastic workshop goggles which had been sprayed with white paint to make them opaque. The close fit of the goggles under the eyes and on the upper part of the nose prevented "peeking." For this group, the board was covered when the S entered the laboratory room so that he would not see it prior to the trials. Other procedures for this group were identical with those for the blind groups. The following instructions were read to the sighted visual group:

This is not an intelligence test and there is no hoax or tricks involved.

You see that the end patterns of the figures slide back and forth, but I have one taped in position now.

What I would like for you to do is to equalize the lengths of the long middle parts of the figures by sliding the end part back and forth. I will tell you when to start.

We will do ten trials with the moving part in each of the four positions, upper right, lower right, upper left, and lower left, for a total of forty trials.

The purpose of the experiment is to see what effect the end patterns have on matching the lengths of the middle parts.

This part is very important. Do not attempt to line up the ends by merely setting one vertically under the other. Make your judgements by actually comparing the middle parts. If you do it any other way, you'll be cheating.

It should be noted that the instructions employed procedures for making certain that the blind and the sighted blindfolded groups understood what the task was, and that all groups should concentrate on making an actual comparison of the lengths of the center parts of the figures.

The dependent variable, extent of illusion, was measured by having S slide the movable end of one figure until, in his judgement the horizontal center section of the figures were equal. On all trials one of the figures was fixed at a standard length of 28 cm. (measured between the outside points of the arrows on the short figure, and between the outside edges of the Vs on the other). Extent of illusion was measured on a metric scale drawn on the inside of the sliding end (not visible to the sighted Ss). If the arrow with the ingoing vanes was set longer than the other, a plus score (positive illusion effect) for the trial was recorded. If the figure with the outgoing vanes was set shorter than the other, a plus score was also recorded. If S set the figure with the ingoing vanes shorter than the other (judgement opposite to the illusion) a minus score was recorded. A minus score was also recorded when S set the figure with the outgoing vanes longer than the other. Any minus scores obtained on individual trials were summed algebraically in computing the sum for each block of 10 trials for each S.

Results

Mean error scores per trial for each of the groups were as follows: sighted blindfolded group, +0.78 cm., blinded in adulthood, +1.72 cm., congenital blind, +1.93 cm., sighted visual group, +2.12 cm.

A _t_ test for a true mean was computed for each of the groups, comparing each mean error score with a hypothetical mean of zero (no illusion). In this test, the means of three of the groups, the congenital blind, the blinded as adults, and the sighted visual groups were found to be significantly different from zero, $p < .001$, in each case. The first group, the sighted blindfolded, was also significantly different from zero, $p < .01$. Thus all groups appeared to experience the illusion.

The error scores were analyzed with a 4 x 4 repeated measures analysis of variance. Factor A was the four groups of _Ss_; factor B was the four positions of the adjustable part of the figures, and was repeated on all _Ss_. Each single score in the analysis of variance was the algebraic sum of 10 individual trials for a particular one of the four presentation positions.

Table 2 presents the results of the analysis of variance:

Table 2

Source	df	SS	MS	F
Between _Ss_	39	1611583.694		
A	3	416535.219	138845.073	4.183*
_Ss_ within gps.	36	1195048.475	33195.791	
Within _Ss_	120	618116.250		
B	3	3797.869	1265.956	0.233
AB	9	27180.756	3020.084	0.556
Bx_Ss_ with. gps.	108	587137.625	5436.459	

*$p < .025$

As indicated above, the differences among the means of the four groups in responding to the Mueller-Lyer illusion are statistically reliable, $p < .025$. A Tukey (a) test (Winer, 1962) was computed, comparing all possible pairs of the four means, the means of the total blind group against those of the total sighted groups, plus the combined means of the congenital blind and the sighted visual groups versus those of the combined blinded in adulthood and sighted blindfolded groups. This test showed that the sighted blindfolded group experienced significantly less illusion effect than each of the other three groups, $p < .01$ in each case. None of the other pairs of means were significantly different. The combined means of the total blind group were not significantly different from the combined means of the two sighted groups. Finally, the comparison between the combined congenital blind and sighted visual groups versus the combined blinded in adulthood and sighted blindfolded groups was statistically reliable, $p < .01$, with the latter pair of groups experiencing less illusion than the former. Factor B, presentation position of the stimulus, was not significant, nor was the A x B interaction.

Discussion

The results of these data, as in the studies of Révész (1934), Bean (1937), Hatwell (1960), and Tsai (1967), show that the blind do reliably experience the Mueller-Lyer illusion. This study also showed, as in the Tsai (1967) study, that the extent of the illusion in the blind is not significantly different from sighted persons experiencing the illusion visually. A third finding worthy of note was that the sighted blindfolded group experienced the illusion significantly less than each of the other three groups. All groups could be said to experience the illusion, but the sighted blindfolded group to a lesser degree than the others, who were perceiving the illusion in their more accustomed sensory modes. Perhaps the difference obtained between the combined blinded in adulthood and sighted blindfolded groups compared to the combined congenital blind and sighted visual groups is, to some extent, an artifact of the extreme scores in the sighted blindfolded group. However, this difference does provide some additional support for the validity of the results of the sighted blindfolded group compared with each of the other groups. It is certainly true that Ss blinded in adulthood have had less experience in the haptic mode than have congenital blind and sighted visual Ss in their respective accustomed sensory modes. Thus even when the blinded in adulthood group is combined with the sighted blindfolded (unaccustomed) group, a difference is still obtained between the relatively unaccustomed and the accustomed.

The finding that the blind experience the illusion as well as the sighted supports central theories of visual illusions, such as that of Révész, Koffka's prägnanz theory, Lipp's empathy theory, and Laska's closure theory (Carter and Pollack, 1968), as far as permitting the inference that a central integrating mechanism is involved in visual illusions. The most conservative inference that could be made is that the Mueller-Lyer illusion is not strictly a visual illusion.

These findings also provide support for Thiery's perspective theory and Gregory's constancy scaling theory (Gregory, 1966), in the same general sense as they support other central theories. But, at the same time, the finding that the blind experience the illusion casts a deep shade of doubt on these two theories. Thiery hypothesized that the Mueller-Lyer figures give a perception of depth; that they are perceived as abstractions of common three dimensional objects. For example, the figure with the ingoing fins is hypothesized to represent the outside corner of a building or a similarly shaped object, and the figure with the outgoing fins represents the inside corner of a room. Gregory's theory is also based on this same perspective notion. The fact that the blind perceive the illusion undermines the whole perspective idea because it is hardly possible for them the perceive the forms as abstractions in a manner similar to the sighted person. Visual depth and form is mediated by cues in conjunction with a two-dimensional retinal image, but depth and form perceived haptically, is mediated by the three-dimensional position of the fingers and hands; different cues altogether are involved.

There are two questions posed by the other findings of this study: "Why do sighted persons experience the illusion visually but to a much lesser extent when blindfolded? And, why do blind persons experience the illusion to much the same extent as the sighted?" The following positional memory hypothesis is presented in an effort to answer these two questions:

The results showing that sighted Ss, experiencing the illusion haptically to a much smaller extent that the other groups, obviously suggests that the illusion effect is not as strong in the secondary sensory mode. Ss in the other three groups are experiencing the illusion in the primary sensory mode in which they have learned to conceptualize the relative position of objects lying in space--they are perceiving spatial relationships in a sensory mode in which they are more experienced. Thus it is postulated that the ability to become aware of the relative position of objects in environmental space is learned, and is associated with the primary sensory mode, but to a much lesser extent in the secondary modes. Knowledge of spatial relationships develops in the sighted through vision, but only to a limited degree through the sense of touch. When the sighted are forced into a situation wherein unfamiliar and subtle spatial relationships are present (as when blindfolded) this group cannot construct an integrated field of object relationships from a series of discrete touch percepts quickly and clearly enough to discriminate small positional differences. The effect is as if the sighted should be forced to perform the task with a field of vision only as large as the fingertips. Memory of preceding impressions are rapidly lost in the serial train of touch sensations. The greater susceptibility of the blind to the illusion compared to the sighted blindfolded, suggests that they more quickly conceptualize the overall form of the figures, and as a result, the end patterns are more salient and have a greater effect for them. The hypothesis predicts, therefore, that the blind should possess a better short term memory for spatial relationships than the sighted. An indication of the period of time needed to develop this faculty is provided by the mean period of blindness of the blinded in adulthood group (116.8 months). The mean illusion score of this group, although not significantly different statistically from the congenital group, is nevertheless smaller. A guess would be that a period of several months, at least, is required. One might expect that the hypothesis would predict an increase in the extent of the illusion in sighted blindfolded Ss over a few hours practice. Such is probably not the case, however. Full development of the ability should occur only after several months of actual blindness.

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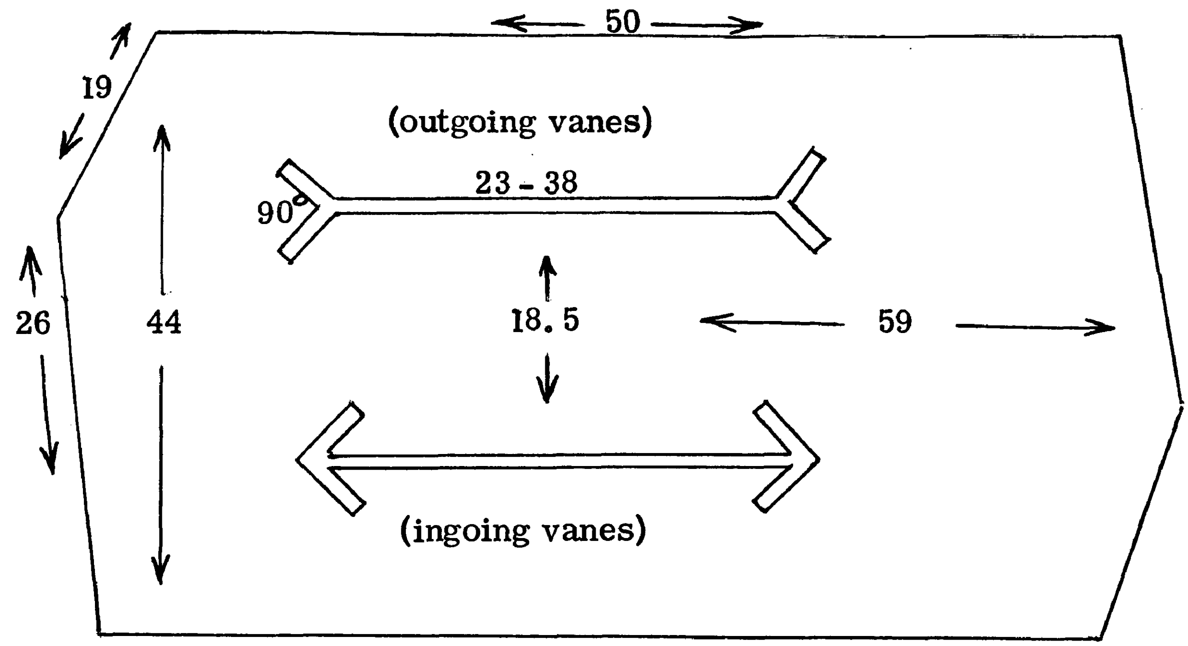
APPENDIX

Table I

Age and length of blindness of the group blinded in adulthood

Age	No. of months blind
22	132
26	60
40	24
41	240
42	15
44	6
44	53
51	432
58	60
59	144
M=42.7	M=116.6

Figure 1



Approximate scale drawing of the apparatus used in the experiment. The Mueller-Lyer figures are white and the board is covered in black felt. Dimensions are in centimeters.